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Population Ageing and Economic Growth in Seven OECD Countries

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Abstract

It is well known that over the next several decades, there will be significant changes in the age structure of OECD populations. According to recent demographic projections by the United Nations, the share of the old-aged population is expected to double, on average, over the next 50 years in the major industrialised countries. These demographic changes may have significant fiscal and economic consequences and pose important public policy challenges for the countries involved.

In this paper, we extend the Hviding and Mérette (1998) computable overlapping-generation (OLG) models for seven industrialised countries in order to examine the impact of population ageing on economic growth. The model is populated by a series of 15 rational overlapping generations that optimally choose life patterns of consumption and bequest. The modified version incorporates endogenous growth, which is generated by the accumulation of both physical and human capital. Typically, a generation invests mostly in human capital when young, and in physical capital when middle-aged.

Our results show that estimates of the long-run economic effects of population ageing are significantly altered when the model features endogenous growth. The results suggest that population ageing could create more opportunities for future generations to invest in human capital formation, which would stimulate economic growth and reduce significantly the apprehended negative impact of ageing on output per capita.

Résumé

C'est un fait reconnu qu'au cours des prochaines décennies, il y aura d'importants changements démographiques pour les pays de l'OCDE. Les Nations Unies anticipent que la part des personnes âgées (65 ans et plus) sur l'ensemble de la population doublera au cours des 50 prochaines années dans les pays industrialisés. Ces changements démographiques pourraient avoir des conséquences fiscales et économiques importantes, et mettent en lumière les défis que devra relever les politiques publiques des pays concernés.

Dans cet article, nous introduisions un second actif (capital humain) au modèle de Hviding and Mérette (1998), ce qui permet d'endogéniser la croissance économique. Hviding et Mérette ont construit pour l'OCDE un modèle numérique à générations imbriquées qui a servi à examiner les effets du vieillissement des populations et de différentes réformes fiscales de 7 pays industrialisés. Le modèle est peuplé par 15 générations imbriquées qui optimisent leurs profils de consommation, d'épargne et d'héritage. Dans la version modifiée, la croissance économique est générée par l'accumulation de capital physique et de capital humain.

Nos résultats montrent que les trajectoires de court et de long terme de l'output per capita sont significativement modifiées quand la croissance économique est déterminée endogènement. Le vieillissement de la population crée des opportunités pour les jeunes d'investir en capital humain, ce qui stimule la croissance économique et réduit significativement l'impact négatif appréhendé du veillissement des populations sur l'output per capita.

1. Introduction

It is a well known fact that, as the baby-boom generation retires, OECD populations will age rapidly over the next several decades. According to recent demographic projections by the United Nations, the share of the old-aged population is expected to double, on average, in major industrialised countries over the next 50 years and the dependency ratio (ratio of dependants to the working-age population) to rise substantially. There is growing concern that these demographic changes will have significant macroeconomic effects and pose difficult fiscal policy challenges.

The potential economic impacts of population ageing have been examined in a number of papers. Some studies have used general equilibrium models with overlapping-generations (OLG) to investigate the effect of ageing on national savings[1]. The results from these studies suggest that population ageing will lead to a sharp reduction in national saving rates and in real output per capita over the next decades.

Ageing may also have an effect on economic growth, depending on the adjustments of factor inputs and on government policy responses. However, the neoclassical OLG models used in previous studies cannot capture these effects because they feature diminishing returns in the reproducible inputs and exogenous technological change, implying that growth is also exogenous in the long run.

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[1] See, for example Hviding and Mérette (1998), Miles (1996), Auerbach *et al.* (1989) and Auerbach and Kotlikoff (1987).

Cutler *et al.* (1990, pp. 55-56) declare in their survey of the economic effects of ageing that:

> We have only scratched the surface in assessing the macroeconomic implications of demographic change. Among the main priorities for future research, we would include the following. First, any effects of demography on the rate of technical change are likely to dwarf its other consequences. It would be valuable to refine our estimates by considering data spanning longer periods and by experimenting with alternative control variables.

The new "endogenous" growth theory developed by Romer (1986), Lucas (1988) and others provides a way of tackling this important issue. In this framework, the return to investment in a broad class of capital goods, including human capital, does not necessarily diminish as economies develop. The framework emphasises factors such as constant return technologies in reproducible inputs, spillover effects and learning by doing, where investment by firms in research and development (R&D), or simply individual investment in both human and physical capital can generate positive growth effects. In an endogenous growth model, the economic impacts of population ageing depend, not only on changes in savings and the labour force, but also on changes in investment in human capital and R&D.

In this paper, we use the OLG models for seven countries developed by Hviding

and Mérette (1998)[2] to investigate the effects of ageing on economic growth and output. We extend the original models by adding endogenous-growth features. The countries examined are Canada, France, Italy, Japan, Sweden, the United Kingdom and the United States. The extended versions are calibrated with exactly the same parameters as in the original models and, consequently, generate the same initial steady states. Our results are thus directly comparable to those obtained by Hviding and Mérette (1998).

The original models are populated by a series of 15 rational overlapping generations (each period in the model corresponds to 4 years), that optimally choose life patterns of consumption and bequest. This framework is similar to that of Auerbach and Kotlikoff (1987). In the extended versions, the models are modified by incorporating endogenous growth, which is generated by the accumulation of both physical and human capital. In endogenous growth models, savings take the form of physical or human capital. Typically, a generation invests mostly in human capital when young and in physical capital when middle-aged. Human capital is specified here and calibrated to generate the same lifetime earnings profile as in Hviding and Mérette (1998). As in the original models, a closed-economy framework is assumed. The specification used for human capital accumulation is similar to that of Lucas' (1988) first model and follows his suggestion of using such a specification in a finite life framework.

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[2] The results of their work were first presented at the Working Party no.1 on Macroeconomic and Structural Policy Analysis at the OECD, October 1997.

The remainder of the paper is divided as follows: Section 2 discusses the prospective demographic trends for the seven OECD countries considered and the resulting impacts on old-age dependency ratios. Section 3 describes the structure and calibration of the models used for the analysis. Section 4 summarises the baseline simulation results from Hviding and Mérette (1998). Section 5 presents our results with the models featuring endogenous growth. Finally, Section 6 provides some concluding remarks.

2. Ageing and Demographics

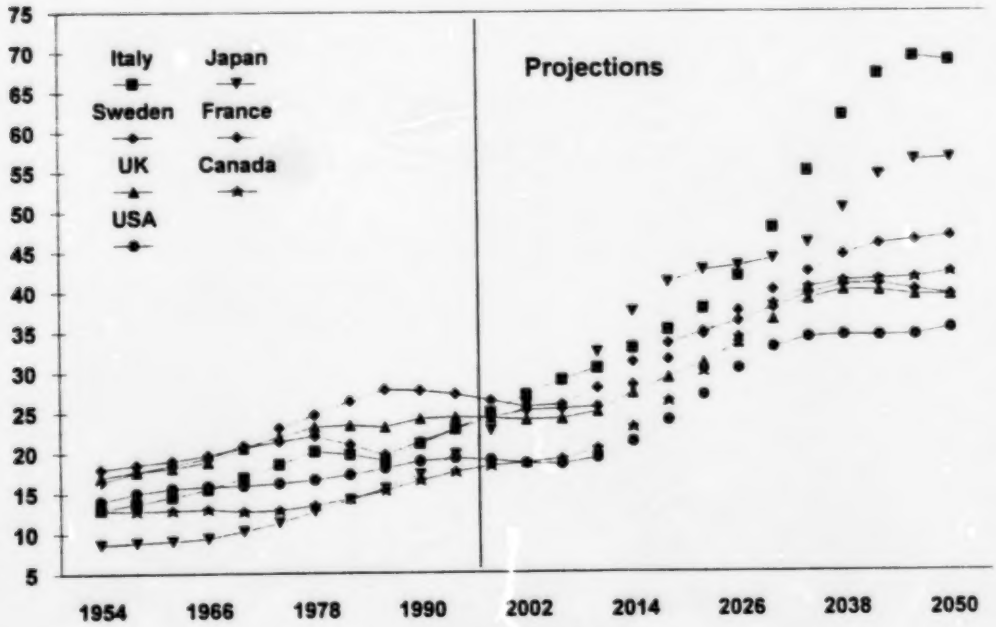
An increase in life expectancy or a drop in the fertility rate (the expected number of births over a woman's life span) are the two major reasons why average population age can increase. In most industrialised countries, a declining fertility rate is the principal source of ageing. In the case of Japan, however, increased life expectancy is also a relatively important factor. According to recent demographic projections, the proportion of the elderly is expected virtually to double over the next 50 years. Of the seven countries examined, Italy and Japan are projected to experience the largest increase in the proportion of old-aged people (see Table 1). Ageing is projected to be least dramatic in Sweden. Canada, France, the US, and the UK rank in the middle.

Table 1
Proportion of Old-Age Population
(as a Percent of Total Population)

	1996	2050
Canada	12	24
France	15	24
Italy	17	34
Japan	15	30
Sweden	17	22
United Kingdom	15	23
United States	13	21

Source: United Nations

Chart 1
Old-Age Dependency Ratios for Seven OECD Countries



Source: United Nations

The old-age dependency ratio (ratio of old-age to working-age population) shown in Chart 1 also illustrates the impact of the bulge in the age structure. In Japan and Italy, the dependency ratio is already increasing rapidly and is projected to rise even faster in the future, rising by 190% and 170% respectively between 1996 and 2050. For the other five countries, the rise in the dependency ratio is more gradual until 2010, but increases at a much faster rate thereafter. For Canada, France and the US, the dependency ratio is expected to increase by 130%, 100% and 90% respectively, over the same period, compared to 60% and 50% for the UK and Sweden.

3. The Models

The Hviding and Mérette (1998) models are based on the life-cycle theory of savings behaviour. In the models, there are 15 generations living side by side at each point in time. Each new generation has 15 periods to live, with each period corresponding to 4 years of life. The 15 generations included are between 16 and 75 years of age. Individuals are assumed to work until age 63, therefore 12 of the 15 generations are members of the active population. Population growth rate is exogenous. The structure of the original models is similar to that of Auerbach and Kotlikoff (1987), with the exceptions of the inclusion of bequest motives and that labour supply is exogenous. The original models assume closed economies.

The Endogenous Growth Extension

In order to incorporate features of endogenous growth, we include human capital formation in the models. As a result, the revised versions feature final goods and post-secondary education sectors. Growth is generated by the accumulation of physical capital produced in the final goods sector, and human capital produced in the post-secondary education sector. Before describing the private and public agents' behaviour, the distinction between human and physical capital will be clarified.

Human Capital versus Physical Capital

Human capital is specified as a non-market good embodied in people with finite lifetimes. Individuals can increase their own stock of human capital by devoting time to schooling. Part of the human capital stock accumulated by living generations is transmitted to future generations. This is consistent with observed aggregate human capital accumulation, and ensures the existence of a balanced growth path. The transmission process is based on the fact that, although each person has only a finite number of years that can be spent acquiring human capital, any nonrival good that this person produces or shares with others lives on after the person dies. The transmission of these nonrival goods is represented by a basic educational institution that transfers a fraction of the stock of human capital accumulated by living generations to succeeding

ones. The basic educational institution disembodies a portion of human capital accumulated by living generations for the benefit of the new cohort. Aggregate human capital can thus grow without bounds. In contrast to human capital, physical capital is a rival and exclusive good that is transferred from existing to succeeding generations through market trades.

The opportunity cost of investing in human capital is the current wage income. Returns to investments in education take the form of a higher stream of net revenue from future labour supply. Investment decisions concerning both assets have life-cycle characteristics because of the specific properties of physical and human capital. Since the returns to human capital are the discounted sum of future wage revenues, it is optimal to invest in the post-secondary education sector when young. As the principal of the physical asset can be sold, this asset will be preferred for old aged retirement preparation. The 15 generations can thus be divided into three important groups: the young, the middle-aged, and the old. The young invest mainly in human capital and work a little, the middle-aged invest mainly in physical capital and work a lot, and the old neither save nor work.

Human Capital Sector

The post-secondary education (human capital formation) production is described

by a well-behaved technology, linear with respect to human capital, but strictly concave with respect to schooling time. This technology implies that the marginal productivity of schooling time is the same for all individuals. All cohorts are thus equally capable of augmenting their stock of human capital. The accumulation motion of human capital for an individual investing a fraction z of his time at period t into human capital formation takes the following form:

$$(1) \quad h_{t+1} = \frac{h_t}{1+\chi(g)} + Bh_t z_t^{\gamma} \quad , \quad B>0;\ 0<\gamma<1;\ \chi>0,$$

where h is the embodied human capital stock, $\chi(g)$ the exogenous human capital depreciation rate and B is a scaling factor. For each generation, $\chi(g)$ is calibrated in order to replicate the earnings profiles of the original models.

The plausible assertion that post-secondary education is relatively human capital intensive is here translated into an extreme specification in which only human capital and education time are used to produce new human capital. Physical capital plays no role. A broadening of these assumptions, which would preserve the factor intensity orderings used here, is not likely to change the basic dynamics of the model. Total production of new human capital in the economy is simply the sum of all individuals' production.

The basic educational institution transmits to the new born at period t an initial

human capital stock h_t^1 that equals a fraction π of the sum of human capital stocks accumulated by its predecessors at the end of period *t-1*:

$$(2) \qquad h_t^1 = \pi \sum_{g=1}^{15} h_{t-1}^g \quad .$$

The human capital stock transmitted to the new born is an automatic social bequest, involuntarily made by the elders. Therefore, the basic educational institution introduces a non-rival, non-exclusive good into the model. Non-rival, because all members of a new cohort benefit to the same extent from previous investments made in human capital, regardless of the population growth rate. Non-exclusive, because predecessors cannot benefit financially from this transfer, as the necessary market is missing. The basic educational institution could be specified as a public institution financed by general taxation, but to facilitate the comparison with the models, this institution is assumed to be free from public charge. The parameter π is calibrated to replicate the same labour productivity growth rate in the initial steady state of the original models.

Since z is the fraction of time allocated to human capital formation, *(1-z)* is working time. Thus, the stock of effective labour supply equals the stock of human capital allocated to the labour market:

(3) $$L_{e,t} = \sum_{g} h_t^g \left(1 - z_t^g\right) pop_t^g \ ,$$

where pop^g_t is the number of people of age g at period t. Equations (1) to (3) constitute the main differences when compared with the models. The effective labour force is determined by demographic trends, but also by human capital allocation decisions. In Hviding and Mérette (1998), the labour-augmenting technical progress is exogenous, so the effective labour force is determined exogenously by the rate of technical progress, and evolves with the changing age composition of the population.

Final Goods Sector

Final goods sector production depends on physical capital and effective labour. All firms are identical and the production technology is assumed to be Cobb-Douglas:

(4) $$Y_t = AK_t^{\varepsilon} L_{e,t}^{1-\varepsilon} \ ,$$

where Y is real output, A a scaling variable, K the stock of physical capital, L_e effective labour and ε the capital income share. Physical assets are accumulated by forgoing consumption, which is equivalent to assuming that physical capital goods are produced in a separate sector that has the same technology as the final-output sector.

Factor demands stem from profit maximization by firms. Firms rent physical

capital at the endogenous rental rate, and hire labour at the endogenous wage rate per unit of effective labour, up to the point at which their marginal products equal their marginal costs:

$$(5) \qquad r_t - \delta = \varepsilon A K_t^{\varepsilon-1} L_{e,t}^{1-\varepsilon} \quad ,$$

$$(6) \qquad w_t = (1-\varepsilon) A K_t^{\varepsilon} L_{e,t}^{-\varepsilon} \quad ,$$

where r is the rental rate (net of depreciation) of physical capital, w is the effective wage. The firm's wage bill is thus the product of the gross effective wage rate times the stock of human capital allocated to the labour market by all existing individuals.

Cohort Behaviour

There is a representative individual for each generation in the household sector. Each individual maximises an intertemporal utility function with consumption and bequests as arguments. Bequest motives are specified as in Blinder (1974). The representative generation's preferences are represented by the following constant intertemporal elasticity of substitution utility function:

$$(7) \quad U = \frac{1}{1-\theta} \sum_{g=1}^{15} \left(\frac{1}{1+\rho} \right)^g \left(c_g^{1-\theta} + \beta_g^{\theta} Beq_g^{\,1-\theta} \right), \; 0 < \theta < 1; \qquad \beta_{g \neq 15} = 0, \; \beta_{g15} \geq 0,$$

where c is consumption, ρ the pure rate of time preference, θ the inverse of the intertemporal elasticity of substitution, β is a constant parameter and *Beq* is bequest.

The optimization problem is subject to human capital (equation (1)) and physical wealth accumulation conditions. The current period budget constraint governs the physical wealth accumulation in the following manner:

$$(8)\ a_{k,j+1} - a_{k,j} \leq w_t h_t (1 - z_t)(1 - \tau_{w,t}) + r_t (1 - \tau_k) a_{k,j} - (1 + \tau_s) c_t + pen_t (1 - \tau_{w,t}) - Beq_t + Inh_t ,$$

where a_k is physical wealth asset, w and r are the wage rate and interest rate respectively, τ_w, τ_r and τ_s are tax rates on labour income, interest income and consumption respectively, *pen* are pensions and *Inh* are inheritances. A generation's lifetime profile of wage income is determined by the fraction of its human capital stock allocated to the labour market. Each generation's interest income is determined by its stock of physical wealth. When an individual is a member of the active population, he/she allocates a portion of his/her time endowment towards work and human capital formation, and allocates disposable income to consumption and savings. Bequests are distributed at the end of each generation's lifetime and are received equally by all working generations. Therefore inheritances are determined by the following condition:

(9) $$Inh_t^j pop_t^j = \frac{1}{12}\sum_m Beq_t^m pop_t^m \quad , \quad j = 1,2,...,12 \text{ and } m = 15.$$

Finally, the amount of pensions received depends on the replacement rate α of wage income earnings during working life:

(10) $$pen_t^m = \alpha \frac{1}{12}\sum_{g=1} w_{t-m+g} h_{t-m+g}^g z_{t-m+g}^g \, , \, m = 13,14,15.$$

Government Behaviour

Government expenditures are restricted to pensions, public goods expenditures, and interest payments on the public debt. Public goods expenditures affect neither private consumption nor production in the model. The government collects three types of taxes from each generation: wage income tax, capital income tax and consumption tax. Tax rates on capital income and consumption are kept exogenous. However, a change in the capital-income or consumption tax base is reflected in the wage-income tax rate. The government's debt instruments are one-period bonds that pay the prevailing market interest rate in the current period and the principal in the next period. The one-period budget constraint of the government is given by:

(11) $D_{t+1} - D_t = r_t D_t + G_t + PEN_t - T_t$,

where D is government bonds, G government expenditures, PEN is total pensions payments ($PEN = \sum_g pen^g pop^g$) and T government revenues from taxation. Summing over all generations, total government revenue is:

(12) $T_t = \tau_{w,t} \sum_g \left(w_t h_t^g (1 - z_t^g) + pen_t^g \right) \cdot pop_t^g + \tau_{r,t} r_t \sum_g a_{k,t}^g \cdot pop_t^g + \tau_t \sum_g c_t^g \cdot pop_t^g$.

The pension system is assumed to be pure "pay-as-you-go" (PAYG) and is fully integrated into government accounts. The government has the responsibility of maintaining solvency of the pension fund by obtaining required contributions from each generation. The public-sector debt-to-GDP ratio is assumed to be constant in the simulation experiments, and the PAYG pension plan is financed through wage-income tax rates.

Equilibrium Conditions

All markets are assumed perfectly competitive. The equilibrium conditions for the two factors of production are guaranteed by equations 3, 5 and 6. To ensure that no resources are wasted, two more equilibrium conditions are necessary. First, physical capital plus government debt equals total private wealth in every period:

(13) $K_t + D_t = \sum_g a^g_{k,t} \cdot pop^g_t$.

Second, final goods output equals household and government consumption plus net investment:

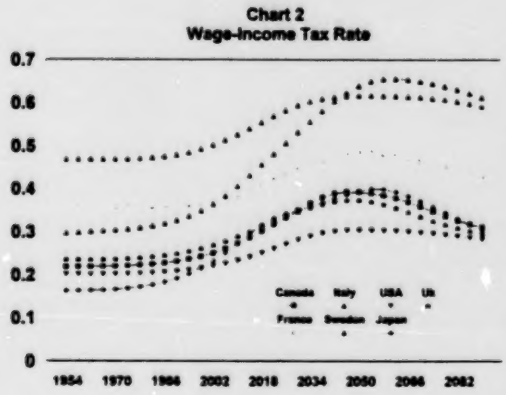
(14) $Y_t = C_t + G_t + I^N_t$,

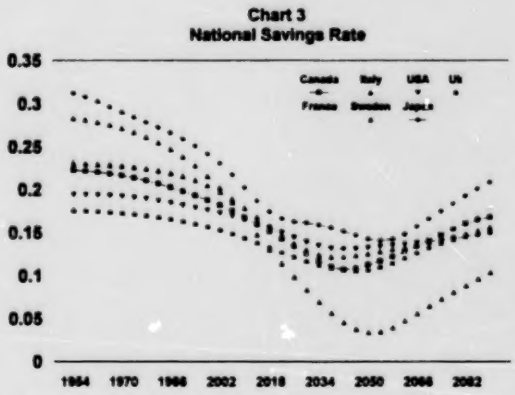
where $C_t = \sum_g c^g_t pop^g_t$ and $I^N_t = K_{t+1} - (1-\delta)K_t$. The values of the calibrated parameters of the model and of the main macroeconomic ratios at the benchmark steady state are presented in Appendix A1.

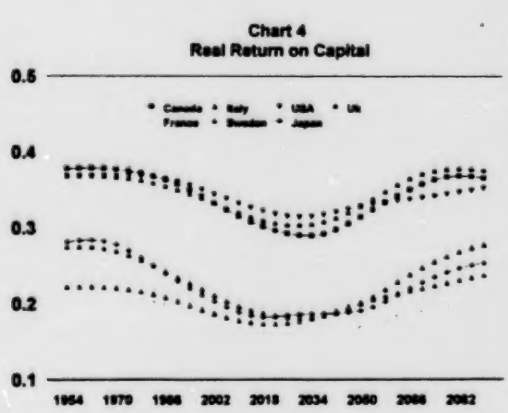
4. Summary of the Hviding and Mérette (1998) Baseline Simulation Results

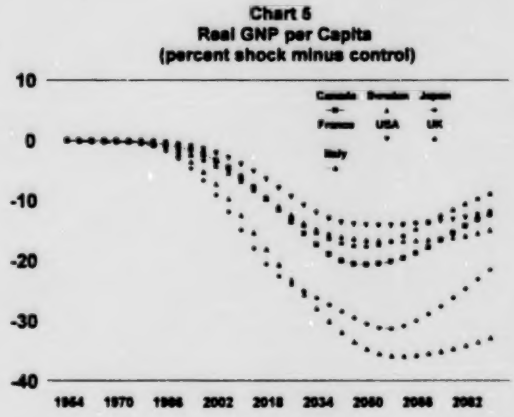
Hviding and Mérette (1998) examined the macroeconomic effects of ageing for seven countries. The demographic shock is simulated through a reduction in the birth rate and begins in 1954. In the long run, it is assumed that the birth rate returns to a steady-state replacement rate. This section summarises their baseline results of the 'pure' ageing effect. The main results are presented in Charts 2 to 5. The results in Charts 2 to 4 present the level of the wage-income tax rate, the national savings rate and the real return on capital. In the absence of the shock, these variables remain equal to their 1954 levels. Chart 5 illustrates the percent shock minus control impact of ageing on real GDP.

In their results, population ageing puts upward pressure on wage income taxes in all seven countries (see Chart 2) because there are fewer workers to finance public pension systems and tax bases thus diminish. Also, the reduction in the capital stock and the real return to capital reduces the capital-income tax base, which puts additional upward pressure on tax rates. The tax rate increases peak between 2034 and 2050, depending on the size of the demographic shock and on the tax structure[3] in each country.









[3] See Table 2 in Appendix A1.

Population ageing also puts significant downward pressure on private and national savings (see Chart 3). As mentioned earlier, the life-cycle theory of savings behaviour is a key assumption of the model and explains the reduction in private savings. The labour force becomes relatively smaller and requires less capital, reducing the need for private savings. Both capital stock and labour force fall, but because the labour force falls further, the capital-labour ratio increases. As a result, the real return on capital falls (see Chart 4) and before-tax real wages increase. Finally, real output per capita also falls for all seven countries, because of reduced labour supply and capital stock (see Chart 5). Italy and Japan are most affected because their demographic shocks are relatively larger than those of the other countries considered.

5. Simulation Results with Endogenous Human Capital

In this section, we present the results of simulating the same demographic shocks on the seven countries, but with endogenous human capital. As shown in Charts A1 to A28 in Appendix A2, the long-run economic effects of population ageing are significantly altered when human capital formation is introduced into the model. This is because the changing age structure of the population now affects the decision to invest in human capital. Population ageing affects human capital formation in two ways. First, by reducing the real return on capital, the present value of future wages increases, which

leads to portfolio reallocations. Agents reduce their investment in physical capital and increase their investment in human capital. Second, wage-income tax rates increase at first, reducing after-tax real wages, but return towards their original levels in the long run. This leads to a change in the investment profile across generations. Young cohorts raise their allocation to investment in human capital, while the middle-aged supply more labour.

Compared to the original exogenous growth results, population ageing increases human capital investment, which leads to a greater reduction in effective labour supply in the short run. It also deepens the reduction in national savings rates and in real output per capita. However, the increase in human capital investment eventually offsets this by raising effective labour supply, which in turn stimulates economic growth. Moreover, in the long run, population ageing has a positive effect on real output per capita compared to a negative one in the original results.

Countries that experience the largest demographic shock are hit hardest initially, in terms of real per capita output and consumption, but benefit the most in the long run via higher economic growth. The increase in average annual rates of economic growth ranges from 0.1 percentage points for the UK, to 0.5 and 0.6 percentage points for Japan and Italy in the long run (see Table 2).

Table 2
Long-run Impact of Population Ageing on Economic Growth

Country	Exo. Growth	Endo. Growth	Change
Canada	2.40	2.64	0.24
France	1.60	1.73	0.13
Italy	2.60	3.20	0.60
Japan	2.40	2.90	0.50
Sweden	2.40	2.64	0.24
UK	2.90	3.00	0.10
US	2.40	2.64	0.24

The offsetting growth effect means that the overall consequence of the demographic shock on other economic variables is more moderate in all countries. Wage-income tax rates increase by much less than in the original results. In the case of Sweden and the UK, for example, the tax rate rises by only 2 percentage points by 2042, compared to about 12 percentage points in the original results. This is explained by the expansion in effective labour supply, which in turn increases the wage-income tax base, and by a smaller reduction in the capital-income tax base.

The reduction in national savings rates is also less pronounced in the long run, although the impact remains negative. It is interesting to note, however, that despite the significant reduction in national savings, economic growth increases in the long run. This reflects the fact that there is a substitution from savings in physical capital to savings in

human capital.

Finally, the real return on capital declines less markedly, although it remains below the level reached in the original resuits in the long run, except in the case of the US. When a new steady state is reached, the capital-labour ratio remains higher with endogenous growth, while interest rates remain permanently lower.

6. Conclusions

In this paper, we have modified the OLG models of Hviding and Mérette (1998) to examine the impact of population ageing on economic growth for seven OECD countries. Our main conclusions are as follows.

First, the macroeconomic effects of ageing are significantly altered when endogenous growth is incorporated in the models. The results suggest that ageing could increase incentives for future generations to invest more in human capital and in turn increase economic growth.

Second, although national savings rates may fall, this does not necessarily imply a permanent real output loss. A reduction in savings could simply reflect a reduction in the optimal level of savings, since the demand for investment in physical capital would have declined. Although physical capital returns could drop, human capital returns could rise.

This would lead to a reallocation from investment in physical capital to investment in human capital.

Third, the tax burden still rises with endogenous growth, but not as much as in the original results. In the case of Sweden and the UK, for example, the increase in the tax burden is modest and temporary.

The simplicity of the models used means that a number of caveats should be stressed. First, all of the countries are assumed to have pure PAYG public pension systems, however institutional realities may be quite different. Canada, for example, has recently announced reforms that will partly fund the Canada and Quebec Pension Plans. If the public pension system is partly funded, then the ageing shock would exert less downward pressure on national savings and the real return on capital would fall even more. In our endogenous growth framework, human capital investment would then increase even more than under PAYG and stimulate growth further. This case is particularly interesting because it suggests that although reduced growth effects may mitigate the negative economic effects of ageing, the underlying endogenous growth channels may, at the same time, reinforce the case for policy reforms like partial funding.

Second, the model does not account for the effect of ageing on government expenditures such as health and education. Ageing is expected to increase health care

spending and to reduce expenditures in education, with the net impact on the tax burden being uncertain. These factors would likely affect our quantitative, but not our qualitative results.

Third, the model does not account for the important changes in the wealth of the elderly arising from savings in sheltered assets like Registered Retirement Saving Plans (RRSP) in Canada and 401(k) plans in the United States. Future decumulation of these asset stocks will raise government revenue and further mitigate required tax increases.

Fourth, the closed economy assumptions are unrealistic for most of the countries examined. It would be worth examining the impacts of ageing under open economy assumptions. There are also alternative ways of introducing endogenous growth in the models, which could alter the results. Alternative sources of growth include spending on research and development and physical capital investment.

These caveats mean that our conclusions must be treated as quite preliminary and any policy implications viewed cautiously.

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APPENDIX A1

TABLE 1:CALIBRATION RESULTS

	ε	δ	η	ρ	α	*K/Y*	*S/Y*	*D/Y*
Canada	34.5	3.10	2.4	.0047	45.9	2.7	22.4	.27
France	33.2	3.02	1.6	.0002	52.16	4.0	23.3	.08
Italy	34.4	2.58	2.6	.0050	45.4	3.6	28.5	.62
Japan	34.2	4.54	2.4	.0025	53.7	2.9	31.8	.09
Sweden	30.0	2.70	2.4	-.003	49.0	3.6	23.1	-.08
United Kingdom	30.4	2.75	2.9	.0035	24.4	2.5	17.6	.35
United States	32.6	3.52	2.4	.0055	42.0	2.5	19.4	.34

TABLE 2: PARAMETERS COMMON TO ALL COUNTRIES

$\gamma = .7;\ 1/\theta = .25;$

Source: Analytical Databank, OECD; Auerbach and Kotlikoff (1987).

TABLE 3: AVERAGE EFFECTIVE TAX RATES: 1965-1994[1]

	τ_k	τ_w	τ_c
Canada	41	22	9
France	22	36	18
Italy	25	30	11
Japan	33	16	5
Sweden	51	47	18
United Kingdom	54	23	13
United States	41	20	5

1. For Sweden, the data are averages of 1975-1994.

Source: Leibfritz *et al.* (1997).

Definitions:

ε: business sector capital income share (per cent)

δ: physical capital depreciation rate (per cent)

η: rate of technical progress (per cent)

K/Y: capital-output ratio

S/Y: gross national saving-output ratio

D/Y: public debt-output ratio

γ: human capital production coefficient

$1/\theta$: intertemporal elasticity of substitution

τ_k: average tax rate on capital

τ_w: average tax rate on wage income

τ_c: average tax rate on consumption

Appendix A2: Charts A1 to A28

Chart A1
Wage-Income Tax Rate (Canada)

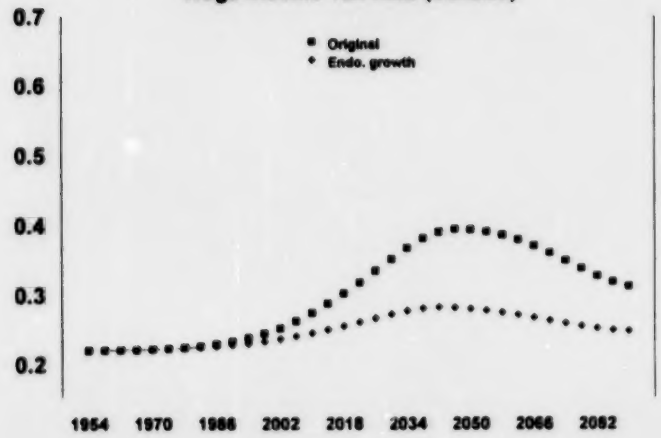


Chart A2
National Savings Rate (Canada)

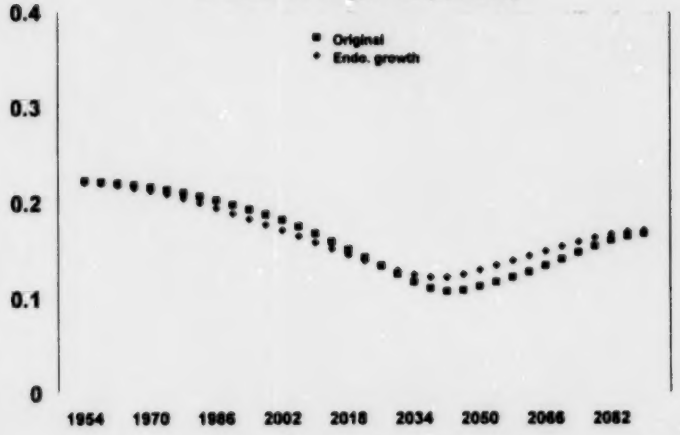


Chart A3
Real Return on Capital (Canada)

Chart A4
Real Output per Capita (Canada)
(percent shock minus control)

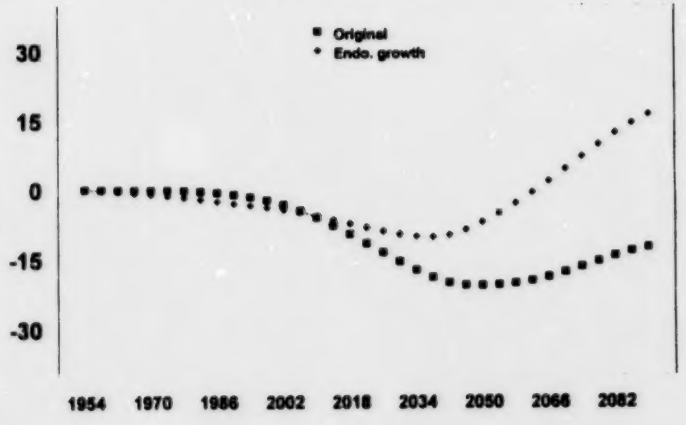


Chart A5
Wage-Income Tax Rate (France)

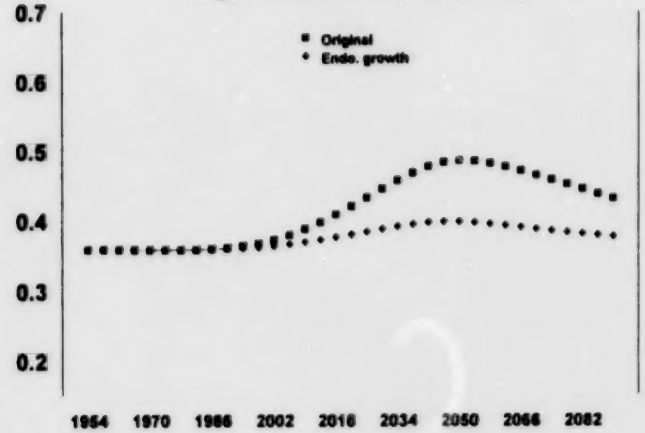


Chart A6
National Savings Rate (France)

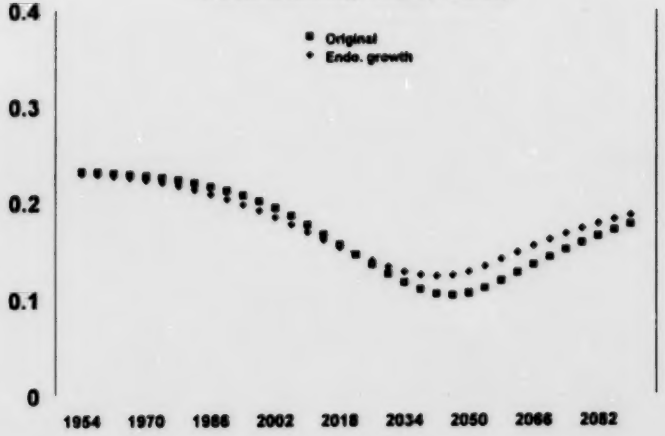


Chart A7
Real Return on Capital (France)

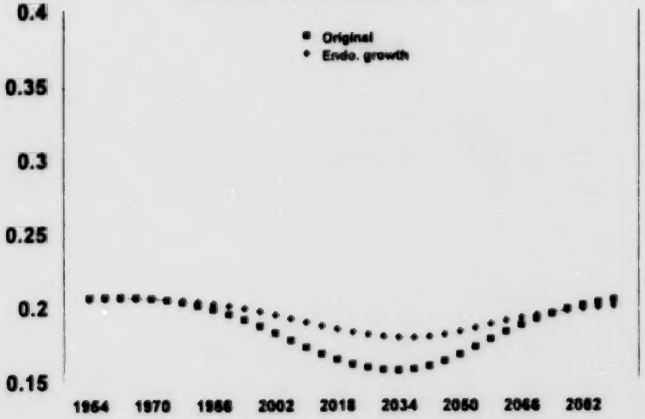


Chart A8
Real Output per Capita (France)
(percent shock minus control)

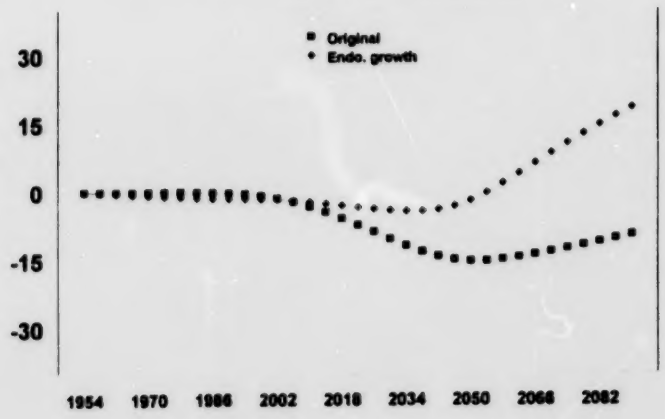


Chart A9
Wage-Income Tax Rate (Italy)

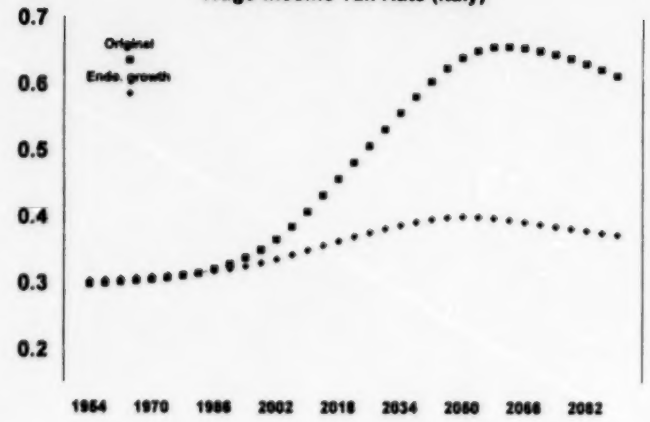


Chart A10
National Savings Rate (Italy)

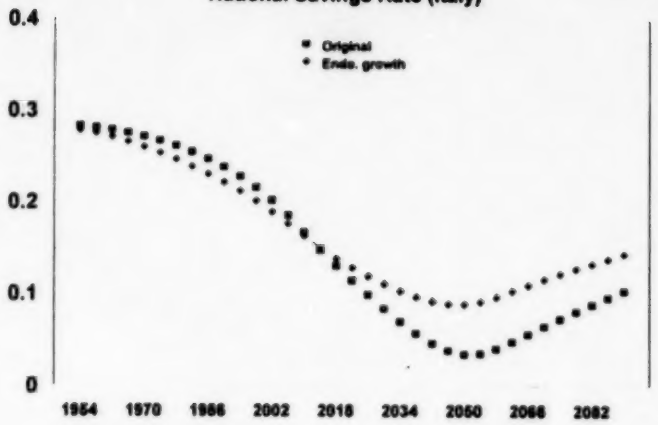


Chart A11
Real Return on Capital (Italy)

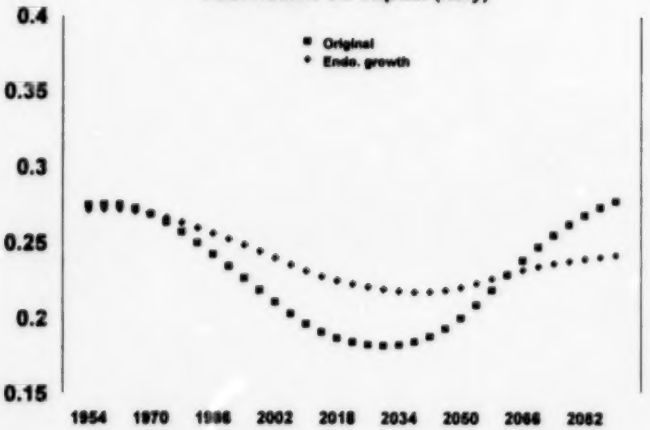


Chart A12
Real Output per Capita (Italy)
(percent shock minus control)

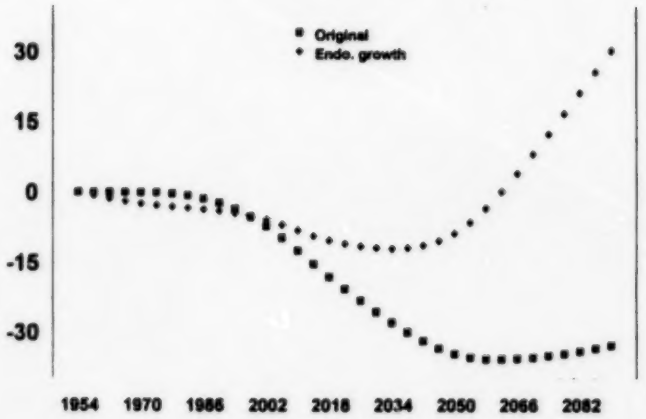


Chart A13
Wage-Income Tax Rate (Japan)

Chart A14
National Savings Rate (Japan)

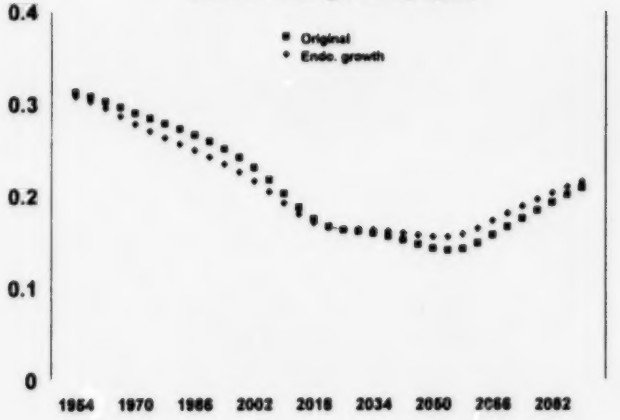


Chart A15
Real Return on Capital (Japan)

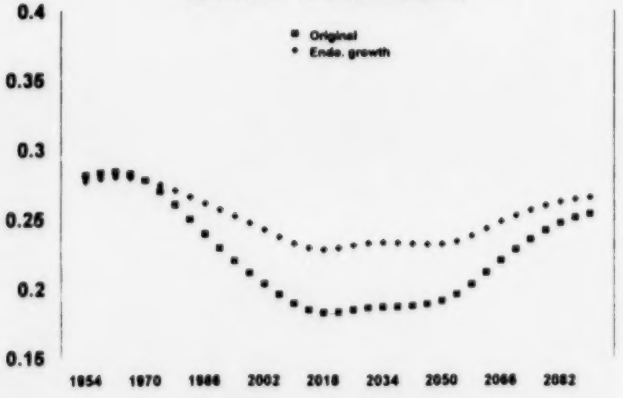


Chart A16
Real Output per Capita (Japan)
(percent shock minus control)

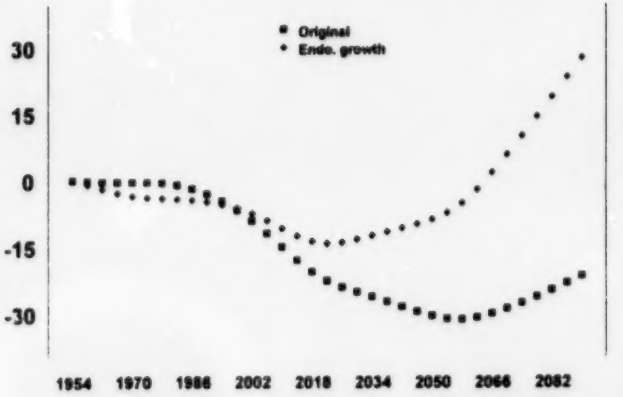


Chart A17
Wage-Income Tax Rate (Sweden)

Chart A18
National Savings Rate (Sweden)

Chart A19
Real Return on Capital (Sweden)

Chart A20
Real Output per Capita (Sweden)
(percent shock minus control)

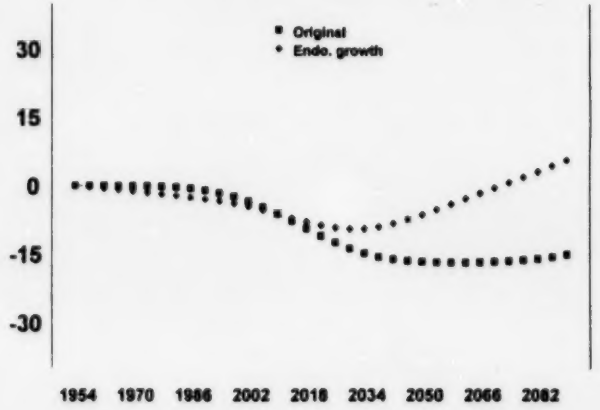


Chart A21
Wage-Income Tax Rate (UK)

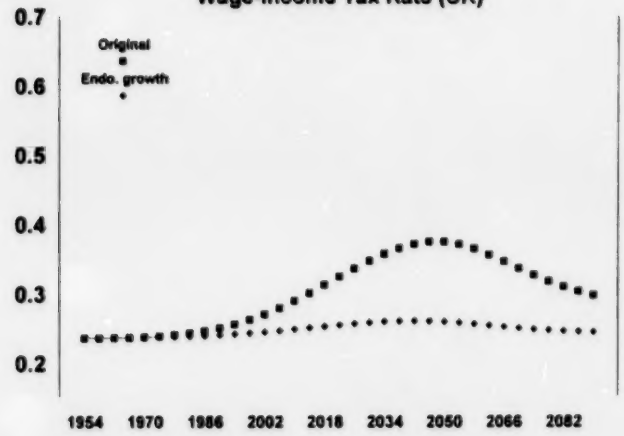


Chart A22
National Savings Rate (UK)

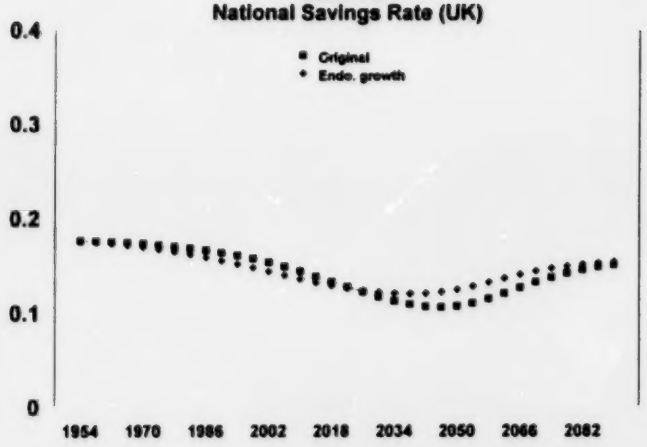


Chart A23
Real Return on Capital (UK)

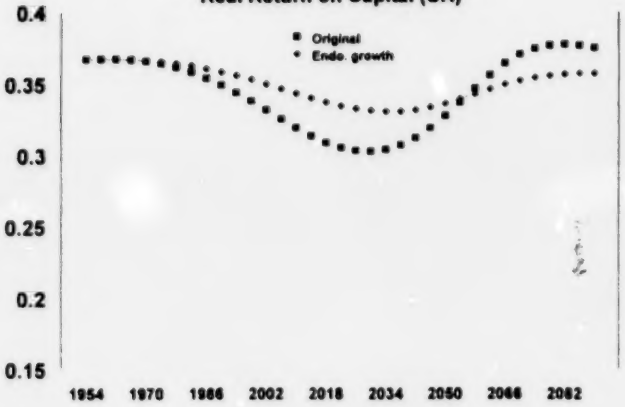


Chart A24
Real Output per Capita (UK)
(percent shock minus control)

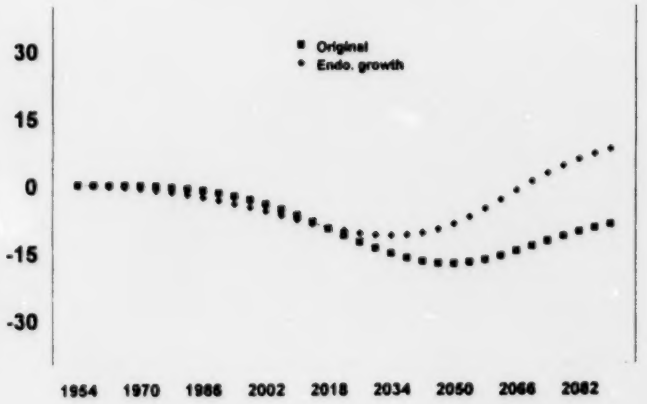


Chart A25
Wage-Income Tax Rate (US)

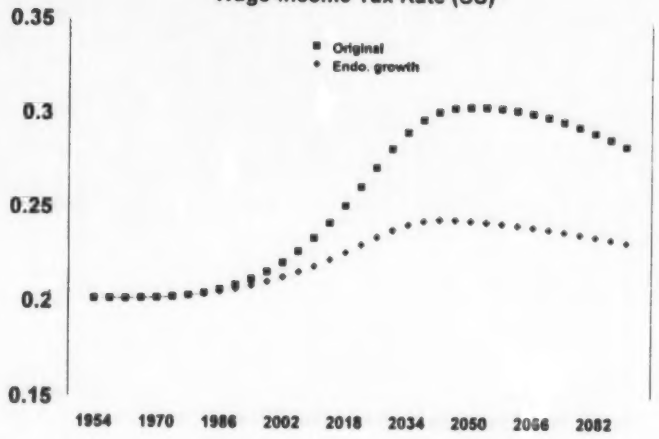


Chart A26
National Savings Rate (US)

Chart A27
Real Return on Capital (US)

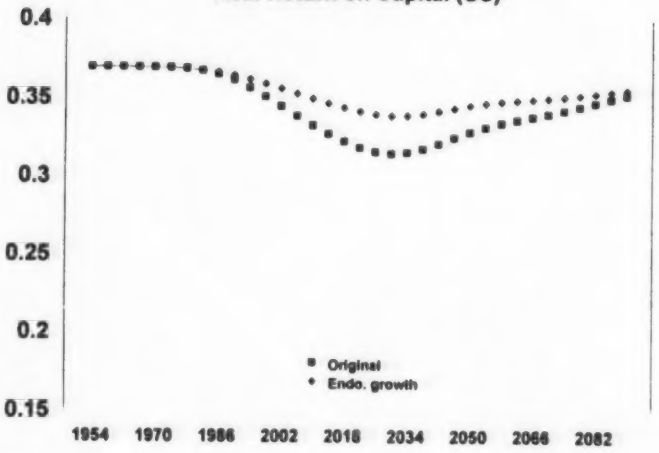
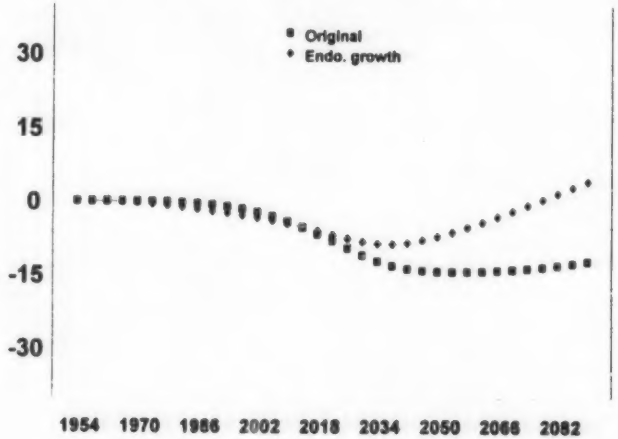


Chart A28
Real Output per Capita (US)
(percent shock minus control)



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